



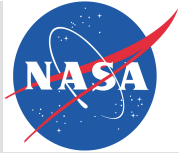
Euclid

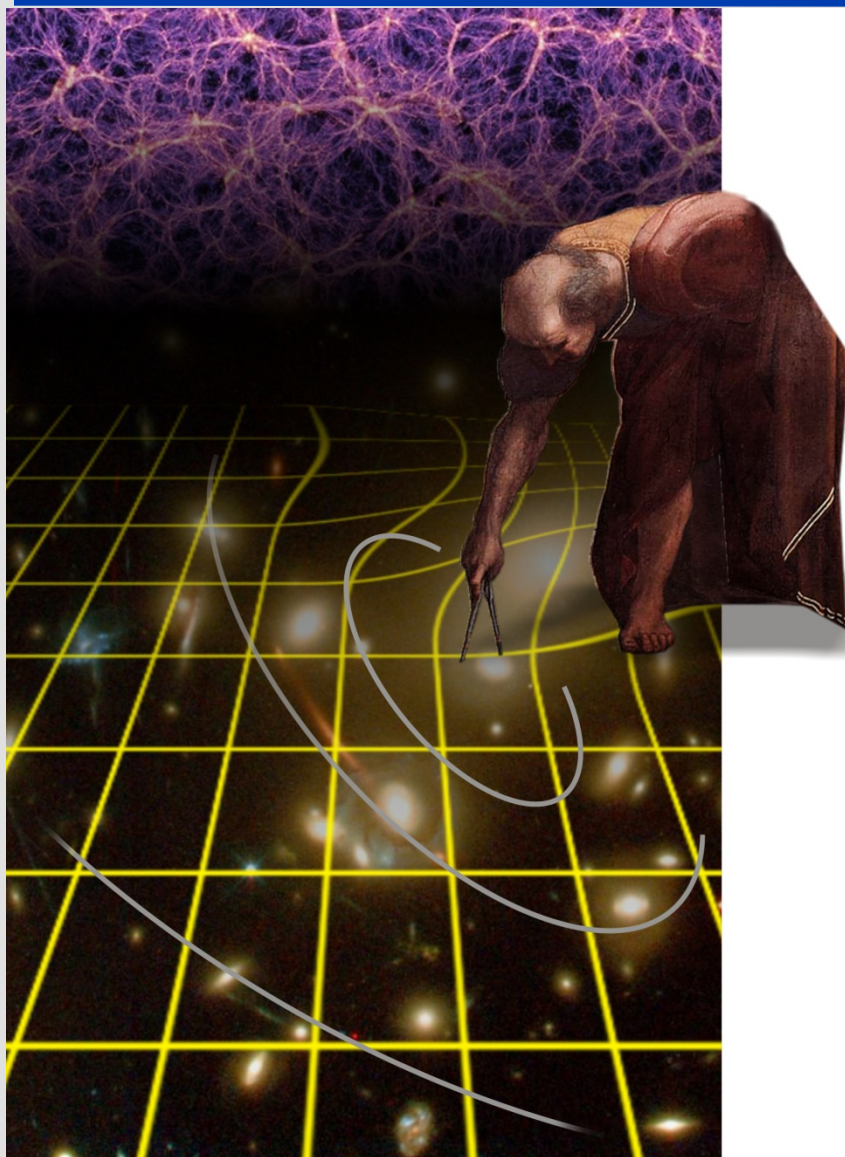
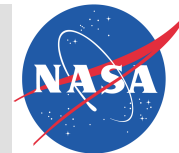
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The Missions





Euclid

Mapping the geometry of the Dark Universe

2004: Dark Universe Mission proposed as a Theme to ESA's Cosmic Vision programme

Oct 2007: **DUNE** and **SPACE** jointly selected for an ESA Assessment Phase

April 2010: Formation of single Euclid Consortium

2010-2011: Definition phase

July 2011: Final Euclid Proposal- Red Book

Oct 2011: **Cosmic Vision Approval of Euclid**

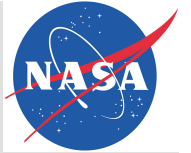
June 2012: Official selection of Euclid and start of implementation

2012-2019: Implementation phase

2019: launch

2020-2026 :science operations

Euclid goals



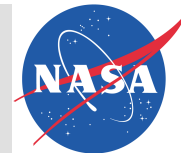
Understand the nature of Dark Energy and Dark Matter by:

- Measuring the DE equation of state parameters w_0 and w_a to a precision of 2% and 10%, respectively, using both expansion history and structure growth.
- Measuring the growth factor exponent γ with a precision of 2%, enabling to distinguish General Relativity from the modified-gravity theories
- Testing the Cold Dark Matter paradigm for structure formation, and measure the sum of the neutrino masses to a precision better than 0.04eV when combined with Planck.
- Improving by a factor of 20 the determination of the initial condition parameters compared to Planck alone.



scientific goals outlined in NWNH Panel Reports:

- How did the universe begin?
- Why is the universe accelerating?
- What is dark matter?
- What are the properties of neutrinos?

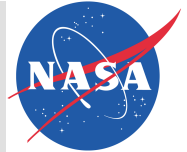


Euclid concept

- **Optimized** for two complementary **cosmological probes**:
 - Weak Gravitational Lensing
 - Baryonic Acoustic Oscillations

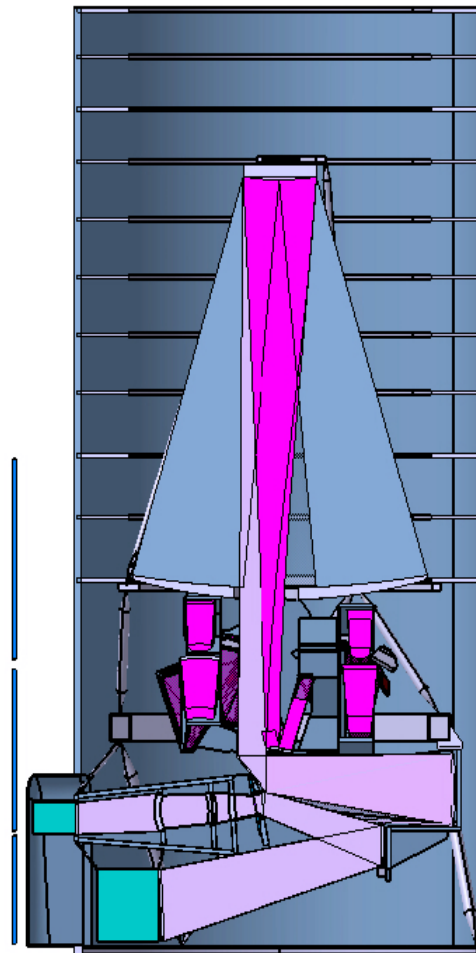
Additional probes: clusters, redshift space distortions, ISW
- **15,000 square degree survey**
 - Imaging (WL):
 - **High precision imaging at visible wavelengths**
 - **Photometry/Imaging in the near-infrared**
 - Near Infrared Spectroscopy (BAO)
- **SN, exoplanet microlensing not part of science goals now**
 - Possible, but not planned

Euclid Mission Baseline

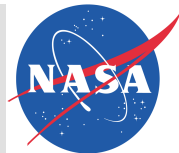


Mission elements:

- L2 Orbit
- 5-6 year mission
- Telescope: three mirror astigmat (TMA) with 1.2 m primary
- Instruments:
 - VIS: Visible imaging channel: 0.5 deg^2 , $0.10''$ pixels, $0.16''$ PSF FWHM, broad band R+I+Z ($0.5\text{-}0.9\mu\text{m}$), 36 CCD detectors, 2/36 CCDs have narrower filter, **galaxy shapes**
 - NISP: NIR channel: 0.5 deg^2 , 16 HgCdTe detectors, $1\text{-}2\mu\text{m}$:
 - Photometry: $0.3''$ pixels, 3 bands Y,J,H, **photo-z's**
 - Spectroscopy: slitless, $R=500$, **redshifts**



One of two possible telescope designs, both obstructed



Impact on Cosmology

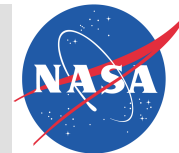
	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	FoM
Euclid Primary [^]	0.01	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.02	2	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2	0.007	0.035	4020
Current*	0.2	0.58	100	0.1	1.5	~10
Factor Improvement	30	30	50	>10	>50	>300

$$f = d\ln\delta_m/d\ln a \propto \Omega_m^\gamma$$

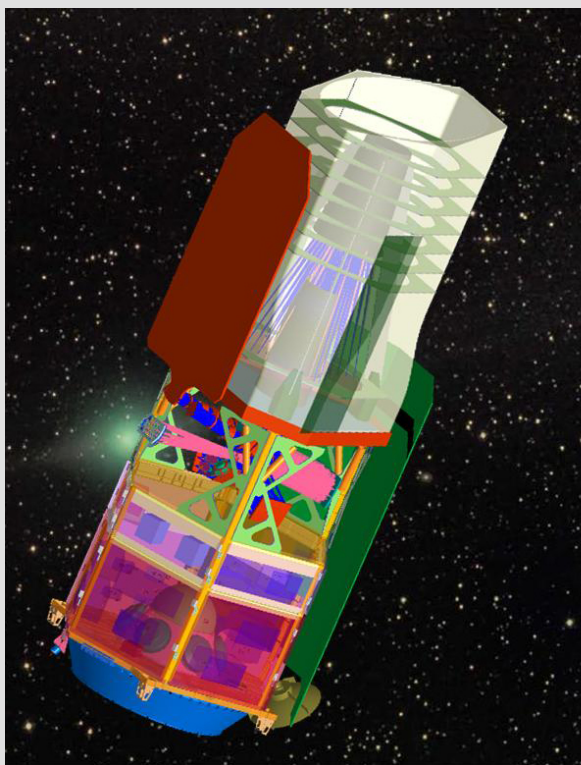
$$w(a) = w_p + w_a \frac{(a_p - a)}{FOM = 1/(dw_p dw_a)}$$

Primary: Five year survey with weak lensing and galaxy clustering from 15,000 deg² of optical/NIR imaging and slitless spectroscopy (RIZ > 24.5, YJH > 24) and DES/PS2 ground-based data

All: Including RSD, ISW and clusters from same survey data



WFIRST =

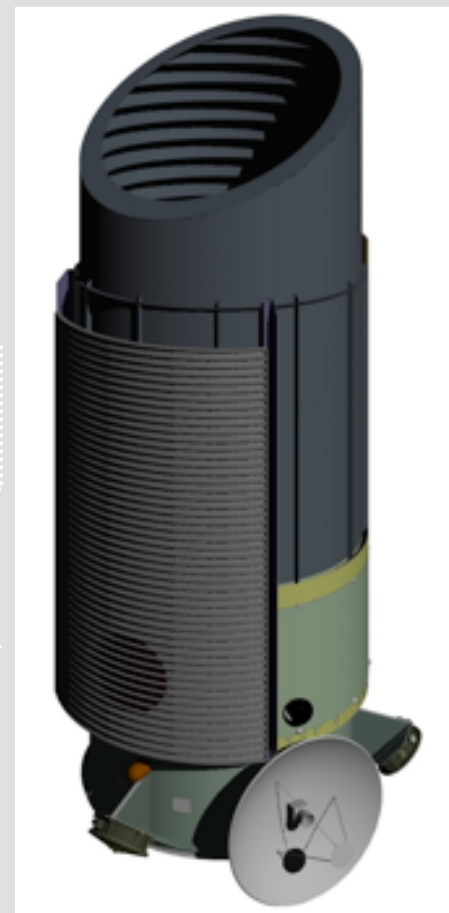


JDEM-Ω

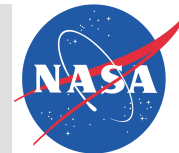
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NIRSS



WFIRST – Science Objectives

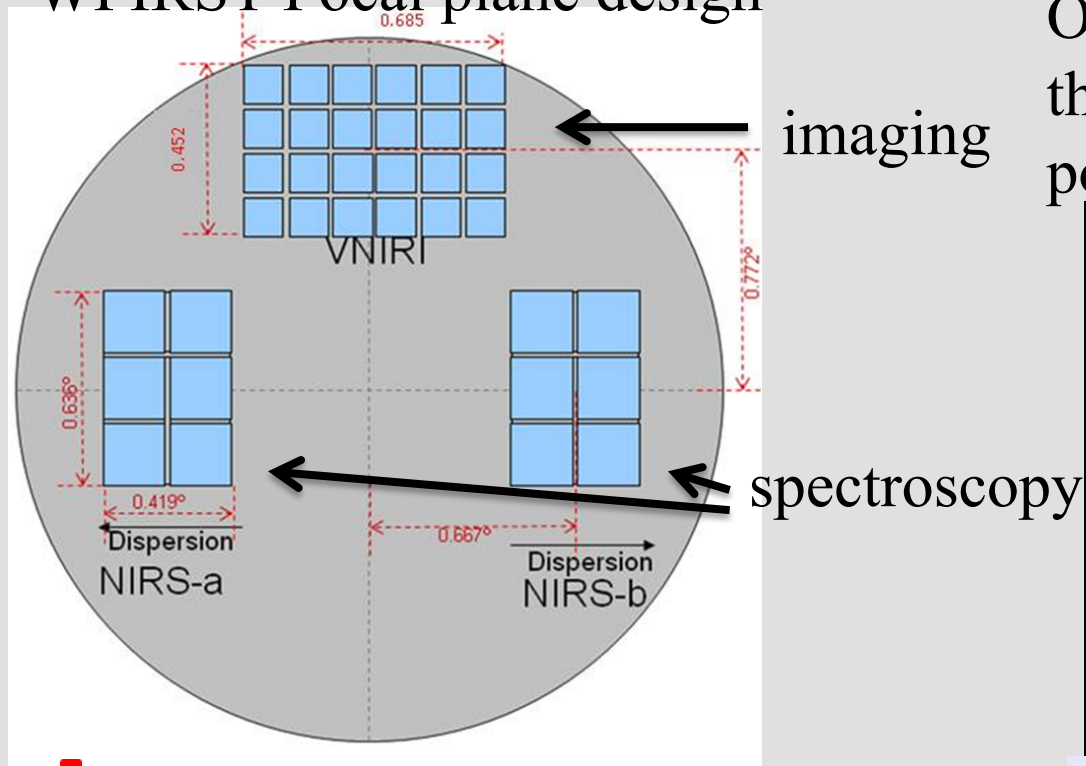
- 1) Complete the statistical census of planetary systems in the Galaxy, from habitable Earth-mass planets to free floating planets, including analogs to all of the planets in our Solar System except Mercury.**

- 2) Determine the expansion history of the Universe and its growth of structure in order to test explanations of its apparent accelerating expansion including Dark Energy and possible modifications to Einstein's gravity.**

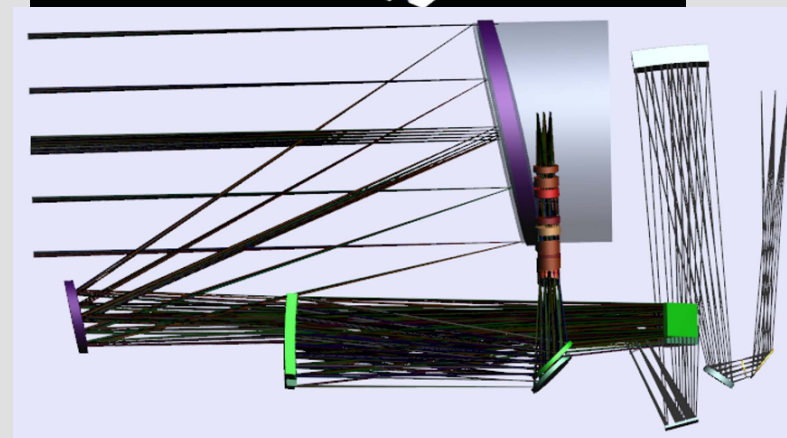
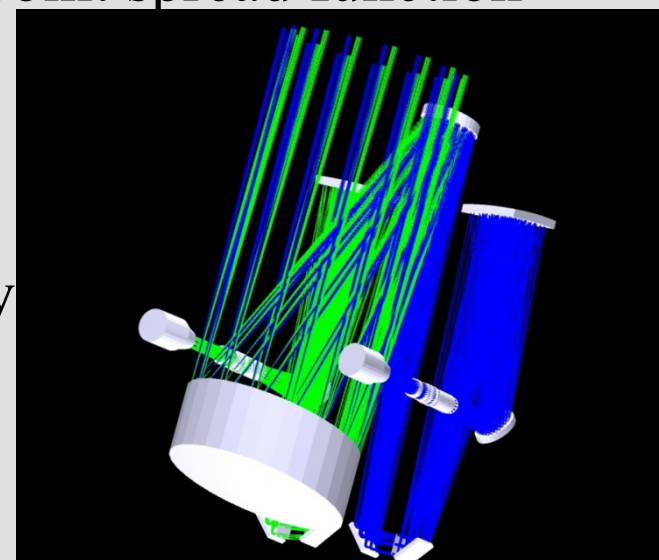
- 3) Produce a deep map of the sky at NIR wavelengths, enabling new and fundamental discoveries ranging from mapping the Galactic plane to probing the reionization epoch by finding bright quasars at $z > 10$.**

WFIRST – A **Survey** Telescope

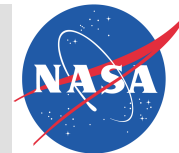
WFIRST Focal plane design



Off-axis design gives high throughput and excellent point spread function



Approximate HST/JWST field of view. These telescopes cannot do WFIRST wide surveys.



Science Return

Mission Performance: EOS Panel/Astro2010 vs WFIRST IDRM

Science Investigation	EOS Panel Report	WFIRST IDRM
WL Survey	4000 deg ²	2700 deg ² /yr
BAO Survey	8000 deg ²	11,000 deg ² /yr
SNe	Not Mentioned	1200 SNe per 6 months
Exoplanet Microlensing	500 total days	500 total days
Galactic Plane Survey	0.5 yr GP Survey	0.5 yr GP Survey
Guest Investigators	1 year GI observations	1 year GI observations

Dark Energy Performance: NWNH Main Report vs WFIRST IDRM

DE Technique	NWNH Main Report	WFIRST IDRM 5 yr mission	WFIRST IDRM 5 yr Dark Energy*
WL Galaxy Shapes	2 billion	300 million (1 yr)	600 million (2 yr)
BAO Galaxy Redshifts	200 million	60 million (1 yr)	120 million (2 yr)
Supernova SNe-Ia	2000	1200 (1/2 yr)	2400 (1 yr)

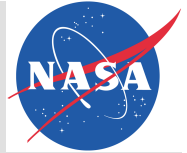
*Including 5 year extended mission



WFIRST and Euclid Do not Work Alone

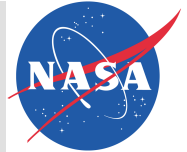
- Both require optical ground based photometry for photo-zs
- Euclid gets shapes in one optical filter that is not very useful for photo-z
- WFIRST does not take optical data in deep survey mode
 - DES in South
 - HSC, LSST, PS2 in North
- Both require significant number of spectroscopic redshifts for photo-z calibration
 - PFS or another facility?

Comparison



	WFIRST IDRM	Euclid
Aperture	1.3m unobstructed (equivalent to 1.5m obstructed)	1.2 m obstructed
Wavelength range	760nm-2 μ m	500nm-2 μ m
Pixel size	018'' NIR imaging 0.45'' NIR spectro	0.1'' optical imaging 0.3'' NIR imaging and spectro
Science goals	DE and modified gravity, exoplanet microlensing, IR surveys	DE and modified gravity, dark matter
Lifetime	5 years primary, 10 years goal	6.5 years primary
Instruments	<ol style="list-style-type: none"> 1. NIR imaging instrument with filter wheel (0.29 deg²) and prism 2. 2 NIR spectrographs (0.26 deg²) 	<ol style="list-style-type: none"> 1. Optical imager (VIS) with fixed filter (s) (0.5 deg²) 2. NIR instrument (NISP) with filter wheel and grism (0.5 deg²)
More info?	http://wfirst.gsfc.nasa.gov/science/WFIRST_IDRM_Report_Final_signed_Rev2.pdf	http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=48983

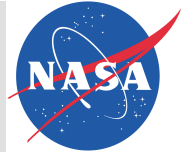
WL Comparison



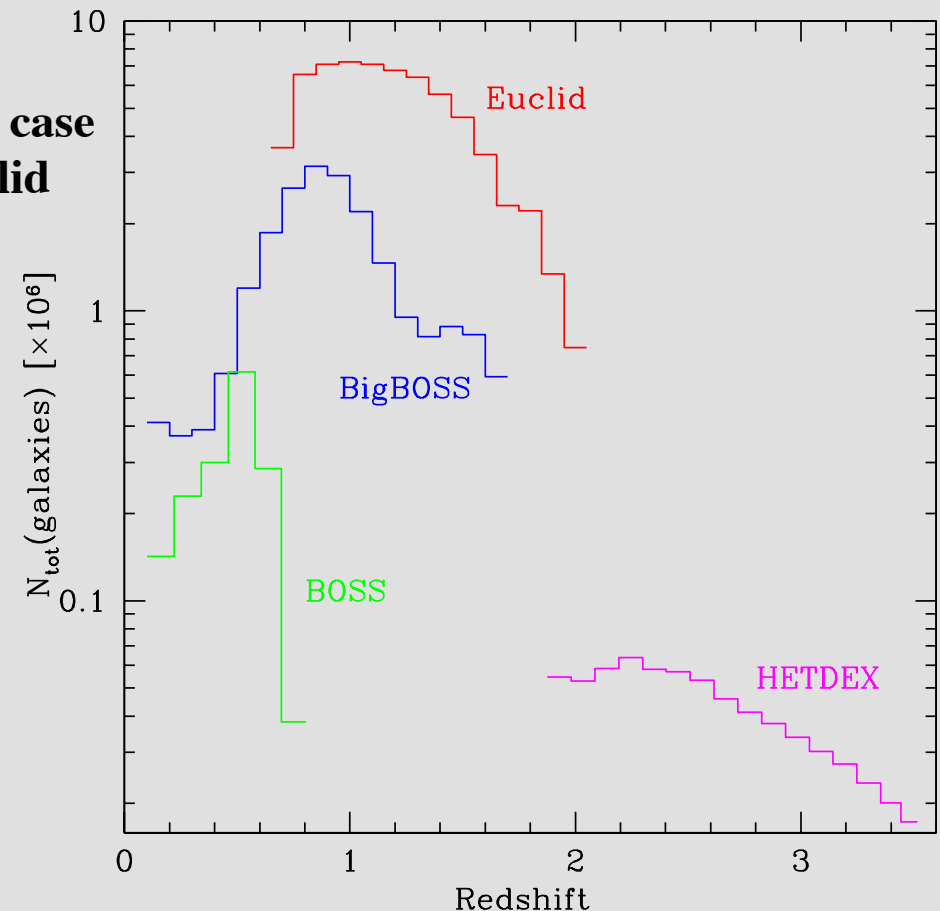
	WFIRST	Euclid
Shape bands	2 NIR bands with shapes	Single wide riz band w/ possible second band on 2/36 CCDs for calibration or calibration with HST data
N_eff	~30	~30
Area	2700 square degrees	15,000 square degrees
Sampling	2 bands well sampled with 5 random dithers	Single band usually well sampled with 4 random dithers but ~50% of sky has only 3 exposures (almost well sampled)*
Ellipticity noise	May be slightly improved due to NIR, but effect is small	Typical optical WL value
Redundancy	Yes	No

* Well sampled is defined in Rowe, Hirata, Rhodes (2011)

Euclid BAO Complementarity with BigBOSS

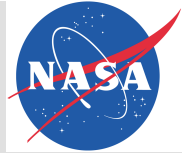


- **Probe different redshift ranges**
- **If BigBOSS goes ahead there is a strong case for decreasing the redshift range of Euclid (i.e. concentrating on $z > 1$)**
 - reduced background limit
 - reduced confusion
 - greater redshift sensitivity
- **Areas will not fully overlap, increasing combined constraints**
- **Cross-checks between overlap regions**
 - BigBOSS could help to calibrate slitless spectroscopy
 - Euclid could help estimate BigBOSS completeness
 - Euclid data will be the benchmark for calibration over large areas



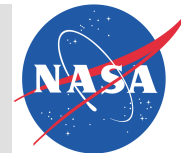
Plot courtesy of Will Percival

BAO Comparison



	WFIRST	Euclid
Line flux	H α emission line flux at 2.0 μm $\geq 1.5 \times 10^{-16}$ erg/cm ² -s (DEEP) or 3.1 $\times 10^{-16}$ erg/cm ² -s (WIDE)	3 10^{-16} erg cm ⁻² s ⁻¹ 3.5 σ unresolved line flux
Area	13,700 square degrees (wide+deep)	15,000 square degrees
Imaging	Simultaneous imaging over different area	Simultaneous optical imaging over same area

“Other” Comparison



μlensing:

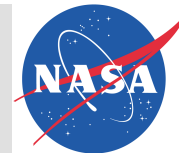
- Euclid could do this, with some loss of sensitivity in optical
- Observing time and baseline are critical
- Some questions remain about number of allowed slews

SN:

- Euclid does not have an observing cadence that makes this efficient in one (of two) industrial design
- Even assuming reaction wheels follow up with grism is not optimal
- Would require dedicated survey time (deep and calibration fields not sufficient)

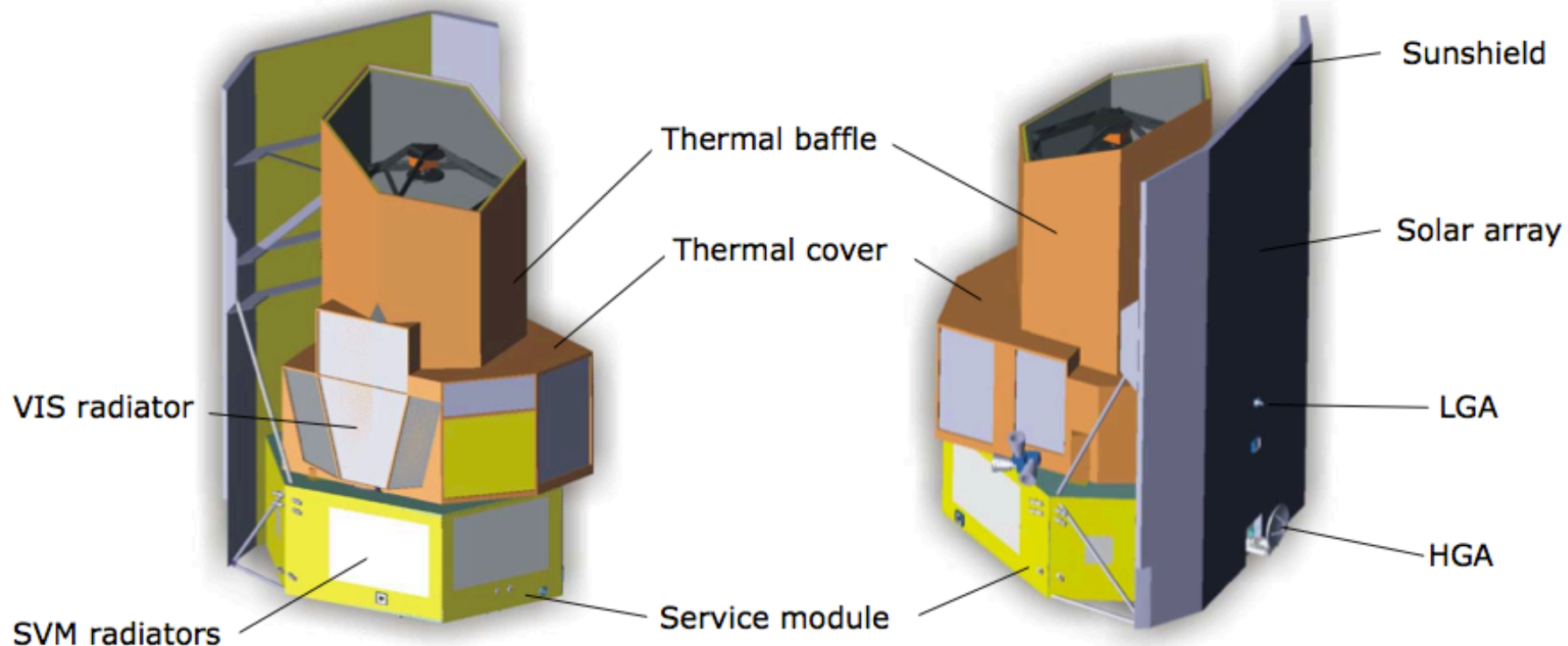
NIR survey:

- Euclid surveys a much larger area with a much poorer resolution



Euclid spacecraft preliminary design

Astrium concept



Euclid spacecraft preliminary design

TAS concept

